

**AN EVOLVING TRIO OF HYBRID STARS: C 111**

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Annual Reports 1 and 2

For the period 1 September 2002 through 31 August 2004

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**Program Title:** An Evolving Trio of Hybrid Stars: C 111  
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## 1 Scientific Activity

Hybrid stars represent the critical evolutionary state between coronal-like objects and the Alpha Ori-like objects. They assume a pivotal role in the definition of coronal evolution, atmospheric heating processes, and mechanisms to drive winds of cool stars. Our FUSE observations of 2 hybrid stars (Gamma Dra and Mu UMa) and one potentially hybrid object harboring a possible planet (Iota Dra), addressed the puzzling problem of the hybrid stage where apparently a “warm” wind/“warm” corona coexist. Only 2 bright members of the hybrid class have been observed with FUSE to date: ( $\alpha$  Aqr in the Cool Stars Team survey, and  $\alpha$  TrA as a GI target).

Our goal is to understand the behavior of the outer atmosphere in this intermediate stage to create a comprehensive picture of atmospheric evolution. In the hybrid phase, the large-scale magnetic dynamo activity decays and hydrodynamic processes assume importance. Some hot plasma is still confined close to the star by magnetic loops, yet the confining field is breaking open, the atmosphere can escape through these open field lines, and the diffuse corona may be warm. Rosner *et al.* (1995) argue that the nature of the stellar dynamo undergoes a topological transition between the two extremes, but it does not address the widely prevalent hybrid objects. There may well be a more extended and variable transition process. It remains for FUSE to identify the controlling parameters of the hybrid stars.

Figure 1 shows the positions of our 3 targets in the color-magnitude diagram where it is seen that they are at the extreme end of the hybrid region. Originally we had been awarded the hybrid star Iota Aur, but due to newly imposed pointing constraints of FUSE, that target was not accessible. And so we substituted Iota Dra, a giant of mass similar to our other targets but less evolved. In addition, Iota Dra was recently found to harbor a sub-stellar objects, possibly a planet, and so it could reveal the stellar environment of the planet. This substitution was accepted.

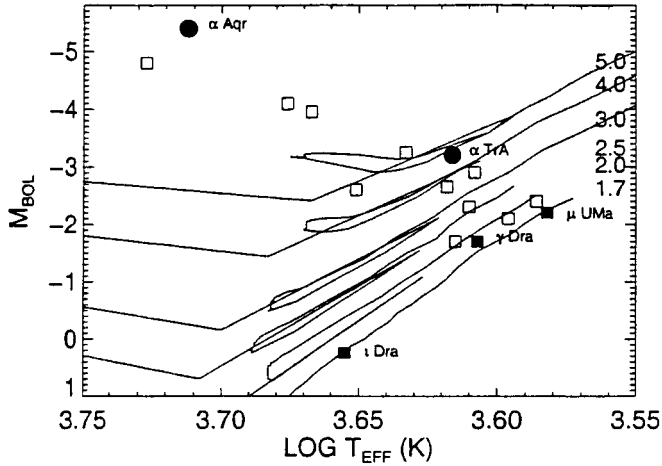


Figure 1: The 3 targets that were observed (*filled squares*) are bright objects that represent a sequence of evolutionary states for stars of mass  $\sim 2M_{\odot}$  and complement the 2 other hybrids observed by FUSE (*filled circles*). Evolution tracks for solar abundance and various  $M_{\odot}$  from Schaller *et al.* (1992, A&AS, 96, 269).

During this reporting period, the last of our observations was obtained and transmitted to us in the spring of 2004. We have reviewed the spectra and all of the stars show the highest temperature species of O VI, although only the two brightest contain the fluoresced species of Fe II, thought to arise in an extended atmosphere.

We have obtained He I 10830Å spectra for these targets, which is important because this line forms a superb diagnostic of atmospheric dynamics in the low chromosphere. Most importantly, we were awarded time on the SOFIN spectrograph at the Nordic Optical Telescope to monitor the chromospheric emissions of Iota Dra, and in particular during the periastron of the planet's orbit which just occurred in the spring of 2004.

These data are being reduced and atmospheric models will be FUSE spectra can be analyzed in a number of ways. For all the spectra, semi-empirical modeling of the atmospheres will be carried out with state of the art codes. Photospheres for the giants can be constructed with Kurucz models. Semi-empirical outer atmospheres will be built using the *PANDORA* code

(Avrett 1996, IAU Symp 176, p. 503). An arbitrary abundance distribution is specified. *PANDORA* solves the complete non-LTE radiative transfer equation, including the effects of expansion and spherical geometry on the line source function and the emergent profiles. Radiative losses are modeled as well as the observed optical and ultraviolet line profiles and fluxes. HST/GHRS spectra are available for  $\gamma$  Dra; high and low resolution spectra from IUE for  $\mu$  UMa and  $\iota$  Aur. We also have optical and infrared spectra for these stars at both the Helium lines ( $\lambda 10830$ ) and Ca II H and K. We expect to find asymmetric resonance lines of C III ( $\lambda 977$ ) that can be modeled in order to determine the velocity field and the mass flux.

We have also used SMULTI extensively for semi-empirical modelling of the supergiant Betelgeuse, and have evaluated the thermodynamic properties of the atmosphere and its velocity structure at a number of different phases.

A model of the Fe II atom can be constructed in order to assess the relative strengths of the Fe II features are expected near  $1135\text{\AA}$ . The appearance of these transitions depends not only on the column density of the stellar atmosphere but the characteristics of the Lyman- $\alpha$  profile that provides the exciting flux and any systematic atmospheric flow that can cause Doppler dimming.

SMITHSONIAN ASTROPHYSICAL OBSERVATORY

MEMORANDUM

DATE: 20 July 2004  
TO: CGPM Department  
FROM: Sara R. Yorke  
SUBJECT: Annual Patents Rights/ New Technology Report  
REFERENCE: Contract/Grant Number: NAG5-12478  
Fund Number: 16613429

There have been no reportable patents/new technology made under this Contract/Grant.



There have been reportable inventions patents/new technology made under this Contract/Grant.



Signature

*Sara Yorke*

Date